

We claim:

1. A method, comprising the steps of:

forming a glass article from molten glass, the glass having an annealing point

5 temperature;

dipping the formed glass article in a molten salt bath, the salt bath comprising potassium
ions wherein the surface temperature of the glass article is at least the annealing point

temperature of the glass during the dipping step; and

maintaining the glass article at a temperature between the strain point temperature of the
10 glass and about 150°C below the strain point temperature for at least about five minutes.

2. The method of claim 1, wherein the surface temperature of the glass article is at least
about 25°C above the annealing point temperature of the glass.

15 3. The method of claim 1, wherein the glass article is dipped in the salt bath for less than
about one minute.

4. The method of claim 1, wherein the glass article is dipped in the salt bath for about 10
seconds or less.

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5. The method of claim 1, wherein the glass article is dipped in the salt bath for between
about 0.5 second and about 30 seconds.

6. The method of claim 1, wherein the glass article is dipped in the salt bath for between about 3 and about 5 seconds.

7. The method of claim 1, wherein the salt bath comprises potassium nitrate and potassium
5 chloride.

8. The method of claim 7, wherein the potassium nitrate is in the range of 40-60 mol% and the potassium chloride is in the range of 40-60 mol%.

10 9. The method of claim 1, wherein the salt bath comprises potassium sulfate and potassium chloride.

10. The method of claim 1, wherein the salt bath comprises a combination of at least two of potassium nitrate, potassium chloride, and potassium sulfate.

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11. The method of claim 1, wherein the salt bath comprises a combination of at least two of potassium nitrate, potassium chloride, and potassium sulfate, the combination having a melting point of at least 550°C.

20 12. The method of claim 1, wherein the salt bath has a temperature of between about 550°C and about 750°C.

13. The method of claim 1, wherein maintaining the glass article is at a temperature between the strain point temperature and about 130°C below the strain point temperature.

14. The method of claim 1, wherein the strain point temperature is about 530°C.

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15. The method of claim 1, further comprising:
flame polishing the glass article prior to dipping the glass article in the salt bath.

16. The method of claim 1, further comprising:

10 after the step of maintaining, cooling the glass article, removing residual salt from the glass article and applying a protective scuff resistant coating to the surface of the glass article.

17. An apparatus, comprising:

a staging area;

15 a glass article moving means;

a salt bath, the salt bath comprising molten salt, the glass article moving means being configured to move the glass article from the staging area and dip the glass article into the salt bath, the glass article moving means being configured to dip glass articles having a surface temperatures of at least the annealing point temperature of the glass, the glass article being
20 configured to remain in the salt bath for less than about one minute; and

a strengtheninglehr, the strengtheninglehr being configured to keep the glass article at a temperature between the strain point temperature of the glass and about 150°C below the strain point temperature for at least about five minutes.

18. The apparatus of claim 17, wherein the glass article moving means is configured to dip the glass article in the salt bath for about 10 seconds or less.

5 19. The apparatus of claim 17, wherein the glass article moving means is configured to dip the glass article in the salt bath for between about 0.5second and about 30 seconds.

20. The apparatus of claim 17, wherein the glass article moving means is configured to dip the glass article in the salt bath for between about 3 and about 5 seconds.

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21. The apparatus of claim 17, wherein the salt bath comprises potassium nitrate and potassium chloride.

22. The apparatus of claim 21, wherein the potassium nitrate is in the range of 40-60 mol%
15 and the potassium chloride is in the range of 40-60 mol%.

23. The apparatus of claim 17, wherein the salt bath comprises potassium sulfate and potassium chloride.

20 24. The method of apparatus of claim 17, wherein the salt bath comprises a combination of at least two of potassium nitrate, potassium chloride, and potassium sulfate.

25. The apparatus of claim 17, wherein the salt bath comprises a combination of at least two of potassium nitrate, potassium chloride, and potassium sulfate, the combination having a melting point of at least 550°C.

5 26. The apparatus of claim 17, wherein the strengtheninglehr is configured to keep the glass article at a temperature between the strain point temperature of the glass and about 130°C below the strain point temperature

27. The apparatus of claim 17, wherein the strain point temperature is about 530°C.

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28. The apparatus of claim 17, further comprising:
flame polishing means, the flame polishing means being configured to flame polish the glass articles.

15 29. The apparatus of claim 28, wherein the flame polishing means is a first flame polishing means configured to flame polish the sides of the glass article, the apparatus further comprising:
a second flame polishing means configured to flame polish the bottoms of the glass articles.

20 30. The apparatus of claim 17, further comprising:
a coating mechanism configured to apply a protective scuff resistant coating to the surface of the glass article after the glass article has been removed from the strengtheninglehr.

31. A glass manufacturing facility comprising a glass forming machine configured to form glass articles, and a strengthening lehr, the improvement comprising:

a salt bath comprising molten salt, the glass articles being dipped into the salt bath for less than about one minute, the glass articles having a surface temperature at least above the

5 annealing point temperature of the glass while being dipped in the salt bath; and

a strengthening lehr, the strengthening lehr being configured to maintain the temperature of the glass articles at a temperature between the strain point temperature of the glass and about 150°C below the strain point temperature for at least about five minutes.

10 32. The glass manufacturing facility of claim 31, further comprising:

a glass article handling means, the glass article handling means being configured to dip the glass articles in the salt bath.

15 33. The glass manufacturing facility of claim 31, wherein the glass articles are dipped in the salt bath for about 10 seconds or less.

34. The glass manufacturing facility of claim 31, wherein the glass articles are dipped in the salt bath for between about 0.5second and about 30 seconds.

20 35. The apparatus of claim 31, wherein the glass articles are dipped in the salt bath for between about 3 and about 5 seconds.

36. The glass manufacturing facility of claim 31, wherein the salt bath comprises potassium nitrate and potassium chloride.

37. The glass manufacturing facility of claim 31, wherein the potassium nitrate is in the range
5 of 40-60 mol% and the potassium chloride is in the range of 40-60 mol%.

38. The glass manufacturing facility of claim 31, wherein the salt bath comprises potassium sulfate and potassium chloride.

10 39. The glass manufacturing facility of claim 31, wherein the salt bath comprises a combination of at least two of potassium nitrate, potassium chloride, and potassium sulfate.

40. The glass manufacturing facility of claim 31, wherein the salt bath comprises a combination of at least two of potassium nitrate, potassium chloride, and potassium sulfate, the
15 combination having a melting point of at least 550°C.

41. The glass manufacturing facility of claim 31 wherein the strengthening lehr is configured to maintain the glass articles at a temperature between the strain point temperature and about 130°C below the strain point temperature.

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42. The glass manufacturing facility of claim 31 wherein the strain point temperature is about 530°C.

43. The glass manufacturing facility of claim 31, further comprising:

flame polishing means, the flame polishing means being configured to flame polish the glass articles.

44. The glass manufacturing facility of claim 43, wherein the flame polishing means is a first flame polishing means configured to flame polish the sides of the glass article, the apparatus further comprising:

a second flame polishing means configured to flame polish the bottoms of the glass articles.

45. The glass manufacturing facility of claim 31, further comprising:

a coating mechanism configured to apply a protective scuff resistant coating to the surface of the glass article after the glass article has been removed from the strengtheninglehr.

46. A method for strengthening a glass article, comprising:

forming the glass article from molten glass, the glass having an annealing point temperature;

applying potassium ions to the surface of the glass article, wherein the surface temperature of the glass article is at least the annealing point temperature of the glass during the applying step; and

maintaining the glass article at a temperature between the strain point temperature of the glass and about 150°C below the strain point temperature for at least about five minutes.

47. The method of claim 46, wherein the step of applying the potassium ions to the surface of the glass article is accomplished by dipping the glass article in a salt bath for less than about 10 seconds.

5 48. The method of claim 46, wherein the glass article is dipped in the salt bath for about 0.5 second and about 30 seconds.

49 The method of claim 46, wherein the step of applying the potassium ions to the surface of the glass article is accomplished by dipping the glass article in a salt bath for between about 3
10 and about 5 seconds.

50. The method of claim 46, wherein the step of applying potassium ions to the surface of the glass article is accomplished by spraying potassium ions on the surface of the glass article.

15 51. The method of claim 50, wherein spraying comprises flame spraying.

52. The method of claim 50, wherein the spraying comprises electrostatic spraying.

53. The method of claim 50, wherein the spraying step comprises power spraying.

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54. The method of claim 46, wherein the step of applying potassium ions to the surface of the glass article is accomplished by chemical vapor deposition (CVD).

55. The method of claim 46, wherein the glass article is at a temperature of at least about 25°C above the annealing point of the glass during the applying step.

56. The method of claim 46, wherein the glass article is at a temperature of at least about
5 50°C above the annealing point of the glass during the applying step.

57. The method of claim 46, wherein the surface of the glass article is at a temperature of at least about 80°C above the annealing point of the glass during the applying step.

10 58. The method of claim 46 wherein maintaining the glass article is at a temperature between the strain point temperature and about 130°C below the strain point temperature.

59. The method of claim 46 wherein the strain point temperature is about 530°C.

15 60. The method of claim 46, further comprising:
after the step of maintaining, applying a protective scuff resistant coating to the surface of the glass article.

61. A method, comprising:
20 forming a glass article from molten glass;
dipping the formed glass article in a salt bath, the salt bath comprising potassium ions, the glass articles being dipped for less than about 30 seconds; and

maintaining the glass article at a temperature between the strain point temperature of the glass and about 150°C below the strain point temperature for at least about five minutes.

62. The method of claim 61, wherein the glass article is dipped in the salt bath for about 20
5 seconds or less.

63. The method of claim 61, wherein the glass article is dipped in the salt bath for about 10 seconds or less.

10 64. The method of claim 61, wherein the glass article is dipped in the salt bath for between about 3 and about 5 seconds.

65. The method of claim 61, wherein the salt bath comprises potassium nitrate and potassium chloride.

15 66. The method of claim 65, wherein the potassium nitrate is in the range of 40-60 mol% and the potassium chloride is in the range of 40-60 mol%.

67. The method of claim 61, wherein the salt bath comprises potassium sulfate and potassium
20 chloride.

68. The method of claim 61, further comprising:
flame polishing the glass article prior to dipping the article in the salt bath.

69. The method of claim 61, further comprising:

after the step of maintaining, applying a protective scuff resistant coating to the surface of the glass article.

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70. The method of claim 61, wherein the salt bath has a temperature of between about 550°C and about 750°C.

71. The method of claim 61 wherein maintaining the glass article is at a temperature between
10 the strain point temperature and about 130°C below the strain point temperature.

72. The method of claim 61 wherein the strain point temperature is about 530°C.